SOME CITRUS SPECIES and VARIETIES in AUSTRALIA

Commonwealth Scientific and Industrial Research Organization, Australia

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SOME CITRUS SPECIES and VARIETIES in AUSTRALIA

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Introduction

Citrus fruits are renowned for their high vitamin C content and are extensively used for their refreshing qualities when consumed either fresh or as juice. Skin and seed oils of some species are used as food additives for flavouring, colouring and perfume. Products from other species are used extensively in the perfume industry.

Some citrus species were introduced into Australia in 1788 by the First Fleet and since then their culture has spread to all States although most commercial production comes from New South Wales, South Australia, Victoria and Queensland.

Citrus is the third largest fruit crop in Australia after grapes and pome fruit. Of all citrus species oranges are by far the largest crop with up to 400,000 tonnes production per annum. Lemon, mandarin and grapefruit production is each only about one-tenth that of oranges (Table 1). Limes, tangelos, kumquats and calamondins are grown to a much lesser extent.

Table 1

Average number of trees (thousands) and production (thousand tonnes) of commercial citrus in Australia for three years 1979, 1980, 1981[1].

	Oranges	Lemons[2]	Mandarins	Grapefruit
Total number of trees planted	5,570	651	509	316
Production	395.7	45.1	31.7	31.0

[1] For year ending 31 March
[2] Includes limes

Seedlings of citrus species are vigorous and thorny, take a long time to come into fruiting and generally produce poor quality fruit, at least in their early years. To overcome these disadvantages selected trees with high yields of good quality fruits are vegetatively propagated by budding or grafting onto rootstocks. Trees produced in this way are uniform and productive and generally free of thorns. Because budwood is selected from mature source trees, progeny trees come into production early without going through a long juvenility period.

While vegetative propagation has the advantage of allowing selection of rootstocks suited to soil and climatic conditions, it has led to the proliferation of virus and virus-like diseases which are spread by grafting but not normally transmitted through seed. These diseases cannot readily be detected but may seriously affect the health and productivity of the progeny.

Such diseases include tristeza, exocortis, psorosis, Citrus dieback and vein enation (see Fraser and Broadbent 1979). To limit the spread of diseases and to provide true-to-type reproduction, a foundation block of

virus tested trees is maintained by the New South Wales Department of Agriculture at Somersby. Virus tested trees propagated from this planting and grown in the Australian *Citrus* repository on the New South Wales Department of Agriculture Horticultural Research Station at Dareton are used as mother trees to supply budwood to commercial nurserymen and growers. The South Australian Department of Agriculture also maintains budwood source trees of virus tested clones at its Loxton Research Station.

Tristeza and Citrus dieback are spread by insect vectors and are difficult to control. Tristeza has been most damaging because it is spread by the black citrus aphid (*Toxoptera citricidus* (Kirkaldy)) which occurs in all citrus growing areas except tropical regions of the Northern Territory and Western Australia. In susceptible stock/scion combinations tristeza causes gumming of the phloem and pitting of the stem at the bud union and eventually unthriftiness and death of trees. It is best combated by choosing tolerant stock/scion combinations. Inoculation of young trees with a mild strain of the disease may at least partially overcome the deleterious effects of a severe infection. The vector for citrus dieback is unknown but it appears to be a native insect which thrives in wet conditions and which is suppressed under hot-dry conditions.

This booklet describes species and varieties of *Citrus* and their near relatives commonly grown in Australia. The native genera *Eremocitrus* and *Microcitrus* are included because they are mostly unique to Australia and are very closely related to *Citrus*. They are graft compatible with true *Citrus* and pollen compatible (at least with some species) and consequently have potential in citrus breeding programs. The native fruits are not grown commercially but fruits collected from native trees are sometimes used for juice.

The plates for each species show longitudinal and transverse sections of mature fruit, seeds where possible, and leaves. It should be noted that skin thickness and colour, flesh colour and juiciness, leaf size and shape and fruit maturity are affected by nutritional and environmental conditions. In particular, the orange skin colour of oranges and mandarins fully develops only when fruits are subjected to low minimum temperatures prior to harvest and the flesh colour of pink and red-fleshed grapefruits and pummelos is enhanced by high maximum temperatures.

With few exceptions the specimens used to illustrate this booklet were grown near Mildura, north western Victoria, by CSIRO Division of Horticultural Research at their field stations at Merbein or Coomealla, or by the New South Wales Department of Agriculture Horticultural Research Station at Dareton.

The exceptions are Ruby grapefruit from Broome, Western Australia courtesy of B. Toohill (Department of Agriculture, Broome). *Microcitrus*

australis from Samford near Brisbane, Queensland, courtesy of D. Hocking (Department of Primary Industries, Brisbane) and *Microcitrus garrowayi* which was a preserved specimen from Iron Range, north Queensland, courtesy of B. Hyland (CSIRO Division of Forest Research, Atherton).

Classification and Nomenclature

Citrus has been classified in the Order Geraniales, Sub-order Geraniineae, Family Rutaceae, Sub-family Aurantioideae, Tribe Citreae, Sub-tribe Citrinae, Sub-tribal group C True Citrus fruit trees (Table 2) (Reuther *et al.* 1967).

Table 2. Botanical Classification of Citrus

Order	Geraniales
Sub-order	Geraniineae
Family	Rutaceae
Sub-family	Aurantioideae
Tribes within	Aurantioideae (i) Clauseneae (ii) Citreae
Sub-tribes within Citreae	(1) Triphasiinae (Minor citroid fruit trees) (2) Citrinae (Citrus fruit trees) (3) Balsamocitrinae (Hard-shelled citroid fruit trees)
Sub-tribal groups within Citrinae	A. Primitive Citrus fruit trees B. Near Citrus fruit trees C. True Citrus fruit trees
Genera within sub-tribal group C, True Citrus fruit trees	Fortunella Eremocitrus Poncirus Clymenia Microcitrus Citrus

The sub-tribe Citrinae is unique in the plant kingdom in that the locules are filled with stalked pulp vesicles. These are structures which grow from the locule walls into the locule cavity. They become filled with large thin-walled cells containing a watery juice. The True Citrus fruits of the sub-tribal group C have slender stems attached to the juice sacs.

There is considerable controversy between different authorities as to the number of valid species within the genus *Citrus*. The main reasons for this controversy are that citrus fruits have been grown by man for many centuries. Early descriptions lack precision so that origins and ranges of natural occurrences are now uncertain. Hybridisation both between and within species occurs readily and the phenomena of apomixis and polyembryony are widespread in the genus. By these means nucellar mother tissue in the developing seed can develop into plants which exactly reproduce the female parent and enable both natural and artificial hybrids to reproduce themselves, that is they come true-to-type from seed.

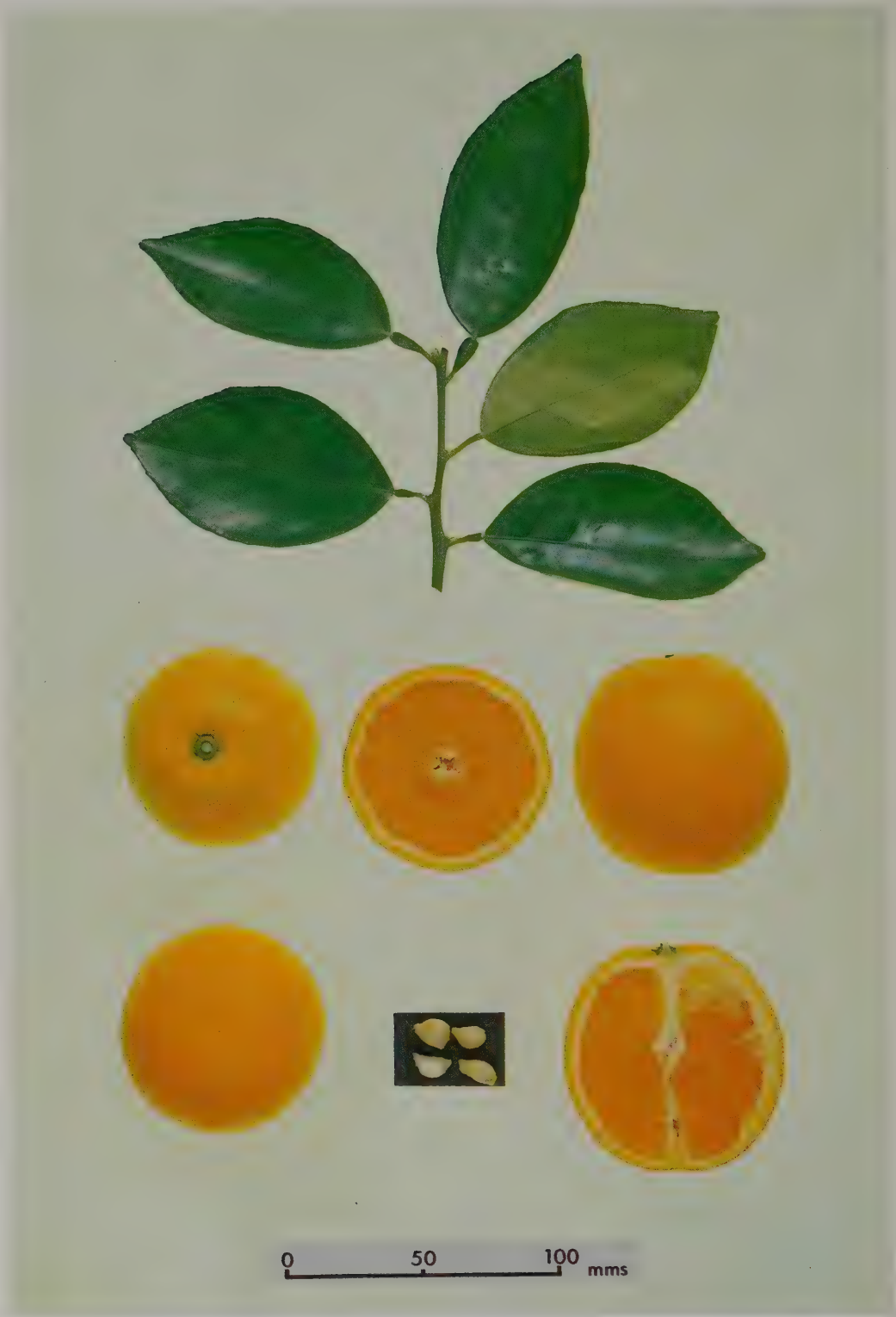
According to whether the authority is a "lumper" or a "splitter" there could be only one species, *Citrus citrus* or more than 159 after T. Tanaka (1969a). Swingle (1943) accepts 16 species and this classification has been accepted by Swingle and Reece (1967).

More recently Scora (1975) and Barrett and Rhodes (1976) have postulated three true biological species, *C.grandis* (L.) Osbeck, *C.medica* L. and *C.reticulata* Blanco, with all others being of probable hybrid origin.

In Australia, Bowman (1956) has accepted the Swingle classification and to avoid further confusion this classification with minor modifications based on the nomenclature used in Hortus Third (Bailey and Bailey 1976), is followed here (Table 3).

Table 3. Nomenclature of citrus described in this booklet.

Scion species	
Sweet orange	*Citrus sinensis* (L.) Osbeck
Sour orange	*Citrus aurantium* L.
Lemon	*Citrus limon* (L.) Burm. f.
Grapefruit	*Citrus paradisi* Macf.
Mandarin	*Citrus reticulata* Blanco
Tangor	*C.reticulata* x *C.sinensis*
Lime	*Citrus aurantifolia* (Christm.) Swing.
Pummelo	*Citrus maxima* (Burm.) Merrill
Citron	*Citrus medica* L.
Tangelo	*C.paradisi* x *C.reticulata*
Round kumquat	*Fortunella japonica* (Thunb.) Swing.
Oval kumquat	*Fortunella margarita* (Lour.) Swing.
Hongkong wild kumquat	*Fortunella hindsii* (Champ.) Swing.
Meiwa kumquat	*F.japonica* x *F.margarita*
Calamondin	(x *citrofortunella mitis*)
Native species	
Australian desert lime	*Eremocitrus glauca* (Lindl.) Swing.
Australian finger li	*Microcitrus australasica* (F. Muell.) Swing.
Australian round lime	*Microcitrus australis* (Planch.) Swing.
Russell River lime	*Microcitrus inodora* (F.M. Bail.) Swing.
Mount White lime	*Microcitrus garrowayi* (F.M. Bail.) Swing.
Maiden's Australian wild lime	*Microcitrus maideniana* (Domin.) Swing.
Rootstocks	
Trifoliata	*Poncirus trifoliata* (L.) Raf.
Sweet orange	*Citrus sinensis* (L.) Osbeck
Citrange	*C.sinensis* x *P.trifoliata*
Citronelle	*Citrus jambhiri* Lush. (*C.limon* hyb.)
Cleopatra mandarin	*Citrus reticulata* Blanco
Emperor mandarin	*Citrus reticulata* Blanco
Rangpur lime	*Citrus reticulata* var. *austera* hyb.
Sour orange	*Citrus aurantium* L.
Macrophylla	*Citrus macrophylla* Wester
Citrumelo	*C. paradisi* x *P. trifoliata*



VALENCIA ORANGE

DHR Merbein November 1978

Sweet orange

Citrus sinensis (L.) Osbeck

The sweet orange is the most commonly grown of all citrus in Australia and two cultivars, the Valencia and navel orange comprise over sixty percent of all citrus plantings. Fruit of one of these cultivars may be obtained from retail outlets in every month of the year.

The tree is evergreen and under favourable conditions may reach about 10m high and 8m wide by the age of 25 years. Trees may live to 100 years but commonly become unthrifty after about 30 years.

The leaves occur in a shell of foliage about 1m thick on the periphery of the tree. Inside shoots are shaded out except where branches become bent down by the weight of crop. Shoot growth occurs in distinct growth flushes. The main one occurs in spring and carries the flowers and fruits. Smaller flushes are produced during summer and autumn. In warm, humid climates, growth flushes are produced continually with little or no rest period. This results in erratic flowering and the production of several small crops in a year. For commercial purposes this has the disadvantage of high harvesting costs and makes mechanical harvesting almost impossible. It may be advantageous for home gardens because ripe fruit is produced almost continually.

Leaves are unifoliate with articulated petioles carrying small wings. The size of leaves varies with the season. Those produced in autumn are larger than spring leaves which in turn are larger than those produced in summer.

Thorniness tends to be associated with leaf size. In commercial cultivars, as distinct from seedlings which are generally very thorny, thorns are produced only sometimes on the autumn flush, whereas the spring and summer flushes are generally thornless.

Flowers are produced either singly in the axils and terminals of vigorous upright shoots or in clusters in horizontal and downward growing shoots. The latter shoot types may be completely leafless. Being an evergreen tree, leaves are shed continuously, but there is a tendency for leaf fall to be greatest immediately before the flowering flush develops.

Valencia The origin of this cultivar is unknown but was probably in China or Indo-China. It was brought to England in 1807 and arrived in Australia very early after European settlement. Improved cultivars were introduced by the Chaffey brothers to the developing irrigation settlements of Renmark and Mildura on the Murray river in 1890.

Because of its adaptation to a wide range of climatic conditions the Valencia is the most widely grown of all orange varieties. It has a high heat requirement and given well watered soil and ample sunshine can produce large crops of excellent quality fruit.

The fruit shape is round or oval depending on the climatic conditions under

WASHINGTON NAVEL ORANGE

DHR Merbein June 1978

which it is grown. With high temperatures, a small diurnal variation and high humidity, fruits tend to be round whereas with a large diurnal temperature variation and low humidity fruits tend to be oval.

The fruit has thin skin, and, depending on rootstock and climate, more than 50 percent juice content. The skin colour is also affected by climate. It becomes bright orange when exposed to light frost during maturity but remains light green when night temperatures remain high. Fruits normally contain two or three plump seeds which have a white testa and white cotyledons.

Fruits mature in August but may be stored on the tree for up to six months. In inland districts such as the Murray and Murrumbidgee Irrigation Areas fruit quality increases to a peak by about mid-November. Fruit held on the tree later than this begins to lose juice from the stem end and the skin tends to regreen. In more northerly areas peak maturity may be reached by mid-September but a similar loss of quality occurs for late harvested fruit.

Flowering occurs in late October so that the tree carries two crops from then to harvest. This tends to encourage biennial bearing which is most marked in the hot-dry inland. Fruit quality factors such as juice content, soluble solids content and a favourable sugar to acid ratio of juice are highest from trees on *Poncirus trifoliata* rootstock followed by those on citrange *(P.trifoliata* x *C.sinensis)*, sweet orange *(C.sinensis)* and citronelle *(C.jambhiri)* in that order.

The appearance of fruit is affected by skin blemishes caused by abrasion of young fruits by leaves due to wind and by thrips and aphids.

Unblemished fruit is sold on the fresh fruit market while surplus and blemished fruit is processed for juice. Processed juice is sold either diluted, full strength or concentrated.

Navel The navel orange was selected in Brazil about 1800 and by 1860 was widely planted there under the name Bahia. A selection of the Brazilian Bahia orange was growing in the Sydney Botanical Gardens in 1828 but the popularity of this variety was not established until the introduction of improved strains from the Azores in 1870 by Moore and from California in 1890 by the Chaffey brothers. The name change from Bahia to Washington navel occurred when an improved selection was introduced in 1870 from Brazil to Washington D.C.

The navel orange is now the most extensively grown early maturing orange. It is commonly used as fresh fruit. The variety has the disadvantage that the juice may contain high levels of limonin which give it a bitter taste on standing.

The navel differs from the Valencia not only in time of maturity but in the presence of a second whorl of carpels at the distal end of the fruit with an opening through the skin, the absence of seeds and the absence of viable pollen.

LENG NAVEL ORANGE

DHR Merbein June 1978

It resembles the Valencia in the general size and shape of trees, the size of leaves and the time of flowering.

The flowers are produced on the spring growth flush but pollen is white and ineffective and not so abundant as with the Valencia. Most fruits are produced parthenocarpically and are seedless. Occasionally fruits with one or two seeds are found. These are generally nucellar and are produced in response to pollination by foreign pollen.

Fruits mature in from seven to ten months after flowering. They may be retained on the tree in good condition for up to 13 months if treated with a "stop-drop" spray of 2-4,D to delay abscission, combined with a spray of gibberellic acid to retain the rind in a juvenile condition.

If harvesting occurs during early winter when fruits are turgid and air humidity is high, careful handling is necessary to prevent rupture of oil cells in the skin. If this occurs, oleocellosis, a rind disorder causing an unsightly browning of the skin develops after a few days storage.

The shape of the fruit is more nearly round than the Valencia. This is no doubt partly due to its limited climatic range. Under high temperature conditions yields tend to be small and juice contents tend to be low. The Washington navel is readily peeled and has distinctive ridges in the skin at the stem end and a slightly depressed button.

Because of the tendency to instability and frequent occurrence of budsports it is necessary to be very selective in choosing budwood for propagation in order to avoid the proliferation of "off types". However sometimes budsports with a particular advantage have been discovered. Both an early and a late maturing budsport are known.

The early one, the Leng navel, was discovered in 1933 on a property at Merbein and subsequently grown and distributed from the Leng property at Irymple in north western Victoria (McAlpin 1982). It has a thinner and smoother skin of a slightly paler colour than its parent, the Washington navel, and matures up to two weeks earlier. The stem end is not as depressed as that of the Washington navel and the oil cells in the skin are smaller. Its juice has a lower limonin content than the Washington navel which gives it a superior processed juice. Because of its thinner skin, this variety requires more careful handling, packaging and transport than the Washington navel in order to arrive at distant destinations in prime condition. The size of fruits on mature trees tends to be smaller than that of Washington navel.

The late sport, Lane's Late navel was discovered on a property at Curlwaa, New South Wales, by Mr. L. Lane in 1954 and has been widely propagated.

It closely resembles the Washington navel but matures about three months later and can be stored on the tree in good condition for up to three months. With longer tree storage its rind holds firm but the internal quality deteriorates.

In addition to these navel sports, navel, and Valencia, there are several mid-

LANE'S LATE NAVEL ORANGE

HRS Dareton July 1982

season orange varieties grown to a limited extent. Mid-season oranges generally contain more seeds than the Valencia but often have a higher juice content. This group includes Mediterranean Sweet, Parramatta, Jaffa, Joppa, White Siletta, Hamlin, Norris, Paterson River, Homosassa, and the blood orange group Maltese Blood, Ruby Blood and St. Michael's Blood. Of these, Joppa is most widely grown, particularly in Queensland. This variety arose in the Chapman orchard, San Gabriel, California and somewhat resembles Valencia. It does best in coastal districts of Queensland where it is preferred to the navel orange. The flesh has a fine texture and a rich flavour.

SOUR ORANGE (ROUGH SEVILLE)

DHR Merbein July 1982

Sour orange

Citrus aurantium L.

This species originated in north eastern India and adjacent regions of China and Burma. It has been in cultivation for thousands of years and was among the first of the citrus species to reach Europe.

Rough Seville in one of its forms is widely grown in Spain but is of minor importance in Australia. The size and shape of the tree resembles that of the sweet orange but it differs in several characters. Leaves are darker green, longer and more tapered and have longer and more broadly winged petioles.

The fruit is flatter with a rougher rind and sunken oil cells. It is coloured a brighter orange than sweet orange and has a thicker skin which is more easily peeled.

The tree is more vigorous, upright and thorny and has been used in many countries as a rootstock because of its good tolerance of the rootrot fungus *Phytophthora* and wet conditions, and resistance to frost and drought. In Australia it is unsuited as a rootstock to all but tristeza tolerant combinations because of its intolerance to this disease for sweet-fruited scions.

The fruit is sour and bitter and widely used for marmalade. Other citrus fruits can be used to make marmalades but these lack the bitter tang of sour orange marmalade.

Smooth Seville This variety is probably a hybrid of Australian origin. It resembles the rough Seville in many ways but has smooth skinned fruit and considerable variability in leaf shape and vigour of seedlings. It has some tolerance of tristeza but has not proved to be suitable as a rootstock. It occurs mainly in collections.

In other countries oils extracted from the skins, seeds, flowers and leaves of the sour orange or its hybrids are used in the perfume industry.

Ornamental varieties such as Chinotto *(C.myrtifolia* Raf.) and Bergamot *(C.bergamia* Risso) are not grown commercially in Australia but are included in collections.

Chinotto, which is probably a sport or hybrid of the sour orange, grows to a small tree. Its small glossy leaves, close nodes and small orange-skinned fruits give it an attractive appearance. Its fruits are small, about 6 to 10 cm diameter, rough skinned and the flesh has a bitter flavour.

Bergamot is probably a hybrid of the sour orange and an acid lime. It is grown in Italy for its essential oil which is used extensively in the perfume industry.

EUREKA LEMON

HRS Dareton July 1978

Lemon

Citrus limon (L.) Burm. f.

The origin of the lemon is shrouded in antiquity but it is now thought to be of hybrid origin. It probably originated in the eastern Himalayan region of southern China and upper Burma and was spread to Europe through India, the Arab Empire and the Crusades (Webber, Reuther and Lawton 1967).

Malik, Scora and Soost (1974), after considering a range of morphological attributes and gas-chromatography studies of leaf and rind oils of lemon-cultivars and possible parental sources, concluded that "citron probably is one of its parents, but an unknown genetic source outside of the citron-lime group also appears to have contributed to its origin".

The lemon is grown extensively for its acid juice which is high in vitamin C and which has a characteristic flavour. It is used for drinks, garnishes and flavourings. Useful biproducts are the essential oils, extracted from skins, which are used as a perfume in soaps and cosmetics.

The tree is more vigorous than that of the orange and more open but it is more sensitive to cold than the orange or mandarin. However at least one variety of lemon can be grown satisfactorily in most regions of Australia where frosts are not severe.

Varieties grown commercially include the Lisbon and Eureka. The Villa Franca which is a Eureka type is grown to some extent in Queensland. The Meyer lemon which is thought to be a lemon x orange hybrid is more frost hardy than other varieties and because it has a wide climatic range, can also produce good crops in the tropics.

The quality of lemons is improved by cool storage because with storage the rind becomes thinner and juiciness increases. Unlike other citrus fruits, lemons produce more than one crop per year. The summer crop is more marked for Eureka than Lisbon which has a main crop in early spring and a much smaller summer crop. Eureka thrives along the New South Wales coast while Lisbon is favoured in drier areas inland and in South Australia and Western Australia because of its greater production under these conditions.

Lemon fruits are oval with smooth skins and a marked point at the distal end. They are produced throughout the tree and not confined to the periphery as are those of orange.

Leaves are oval with rounded crenate serrations and petioles are articulated and wingless. The oil cells in the leaves can be readily distinguished in leaves held up to the light.

Eureka This variety originated in California in seedlings of Italian origin (Reuther *et al.* 1967). It is everbearing and precocious with a thornless, relatively vigorous tree with an open growth habit.

The fruit has a moderately rough skin and is often ribbed. A prominent

LISBON LEMON

DHR Merbein July 1978

nipple on the distal end is frequently surrounded by a circular furrow, the areole, while the stem end has a short neck. Both these features are somewhat variable so that identification cannot be made for certain from a single or even a few fruits. The fruits contain a few seeds which are plump and shaped rather like the fruits. They have a white seed coat.

At maturity the skin is yellow and the flesh very pale green. The juice remains acid although it does contain some sugar. This variety is short-lived on citronelle rootstock.

Lisbon This variety is of Portuguese origin and was introduced to Australia in 1824 (Bowman 1955). It is more vigorous than Eureka and has more or less thorny shoots depending on the selection.

The skin is smoother than that of the Eureka and the areole is less marked but tends to be deeper on one side than the other. The fruit has a less prominent neck than the Eureka. Seediness and internal quality resemble the Eureka.

It tends to mature its fruit mainly in winter and spring with a relatively smaller summer crop than the Eureka. It will outproduce the Eureka in the hot dry inland but the reverse is the case in coastal and humid areas.

The Meyer "lemon" is thought to be a hybrid of lemon x orange. It originated in China and is more frost hardy than the lemon. When mature the fruit has a pale orange skin and less acid than the true lemons. It has a smooth skin and a more rounded fruit than the lemon.

Because of its wide climatic adaptability this variety is a useful household tree particularly for locations too cold or too hot for true lemons.

MARSH GRAPEFRUIT

DHR Merbein July 1978

Grapefruit

Citrus paradisi Macf.

Unlike other citrus which have their origin in the Indo-Malaysian region, the origin of grapefruit is almost certainly the West Indies. Most authorities consider it to be a hybrid with pummelo *(C.maxima)* as one parent, the other being unknown.

It was introduced to Florida early in the nineteenth century and because of its popularity there,was soon distributed to other citrus growing areas.

In Australia the variety Marsh is most widely grown because of its seedlessness while Wheeny (a hybrid) is grown in colder areas. The pink fleshed varieties Foster, Thompson and Ruby are gaining in popularity in northern Western Australia but fail to develop colour beyond a pale or muddy pink in southern areas.

The grapefruit tree is more vigorous than the orange with larger leaves having broadly winged petioles. It can withstand very hot conditions and is about as cold tolerant as the sweet orange. However it has a very high heat requirement and consequently does best in hot climates. Fruits are produced in clusters of three or four.They have a fine pale yellow skin at maturity and are oblate with a slightly depressed distal end.

In southern Australia, grapefruits flower in spring and fruit matures after 12 to 14 months. In the north, flowering may occur as early as July with fruit maturing six months later. Mature fruit may be stored on the tree for several months in southern Australia but in the north it rapidly becomes overmature with puffy skins, hollow centres and associated off-flavours unless harvested when mature.

Grapefruits differ from pummelos in their fruiting habit, lack of hairiness of young shoots and fruits and having polyembryonic rather than monoembryonic seed. Whereas grapefruits develop in clusters on the terminals of young shoots, pummelos fruit from inflorescences which develop from old wood. Pummelo fruits are generally larger and have thicker skins than grapefruit.

Marsh This variety originated as a chance seedling in Florida about 1860. It was the first seedless (or nearly so) grapefruit discovered and soon became the most popular variety. It has a pale yellow skin at maturity and pale yellow flesh containing only a few seeds. The flavour depends on the location where it is grown. In southern Australia the bitter principle in the juice (naringin) is far higher than in northern areas. Skin thickness also decreases from cooler to hotter growing areas. This variety can be stored for long periods on the tree in good condition.

Wheeny Originated as a chance seedling at Wheeny Creek, Kurrajong, New South Wales. It replaces grapefruit in cool and coastal areas because it

WHEENY GRAPEFRUIT

HRS Dareton July 1978

has a lower heat requirement and is tolerant of stem-pit which is caused by a component of the virus tristeza.

Although its fruits superficially resemble grapefruit it is very seedy and has monoembryonic seeds, which suggest a hybrid origin, probably with pummelo as one parent.

Because seedy fruit show less breakdown during canning Wheeny has an advantage in this respect.

Pink fleshed varieties resemble Marsh in morphological characteristics but differ in having pink or red flesh. The best colour development occurs in hot, dry climates such as the north west of Western Australia and north of the Tropic of Capricorn.

The Foster is seedy and originated as a limbsport on a seedling tree in Florida. It was the first pink fleshed grapefruit known to the industry but was soon replaced by the Thompson which is seedless as it is a limbsport of Marsh. The Thomson was also discovered in Florida.

The Ruby or Red blush variety is a limbsport of Thompson. It has reddish rather than pink flesh and has a pink blush on the skin. Tree growth and development of Thompson and Ruby are indistinguishable from that of Marsh.

RUBY GRAPEFRUIT Broome Nursery W.A. March 1981

IMPERIAL MANDARIN

HRS Dareton June 1978

Mandarin

Citrus reticulata Blanco

The mandarin originated in China and south eastern Asia and has been grown in China and Japan since the twelfth and thirteenth centuries. It was introduced into Australia as seeds and plants early after European settlement and by 1828 several varieties were growing in the Sydney Botanic Gardens (Bowman 1956).

This species is gaining in popularity in many parts of the world because of the ease with which peel may be separated from the flesh, and the tangy sweet/acid flavour.

The mandarin or loose skinned orange obtains its species name from the network of white conducting tissue, the reticulum, which surrounds the fruit under the skin.

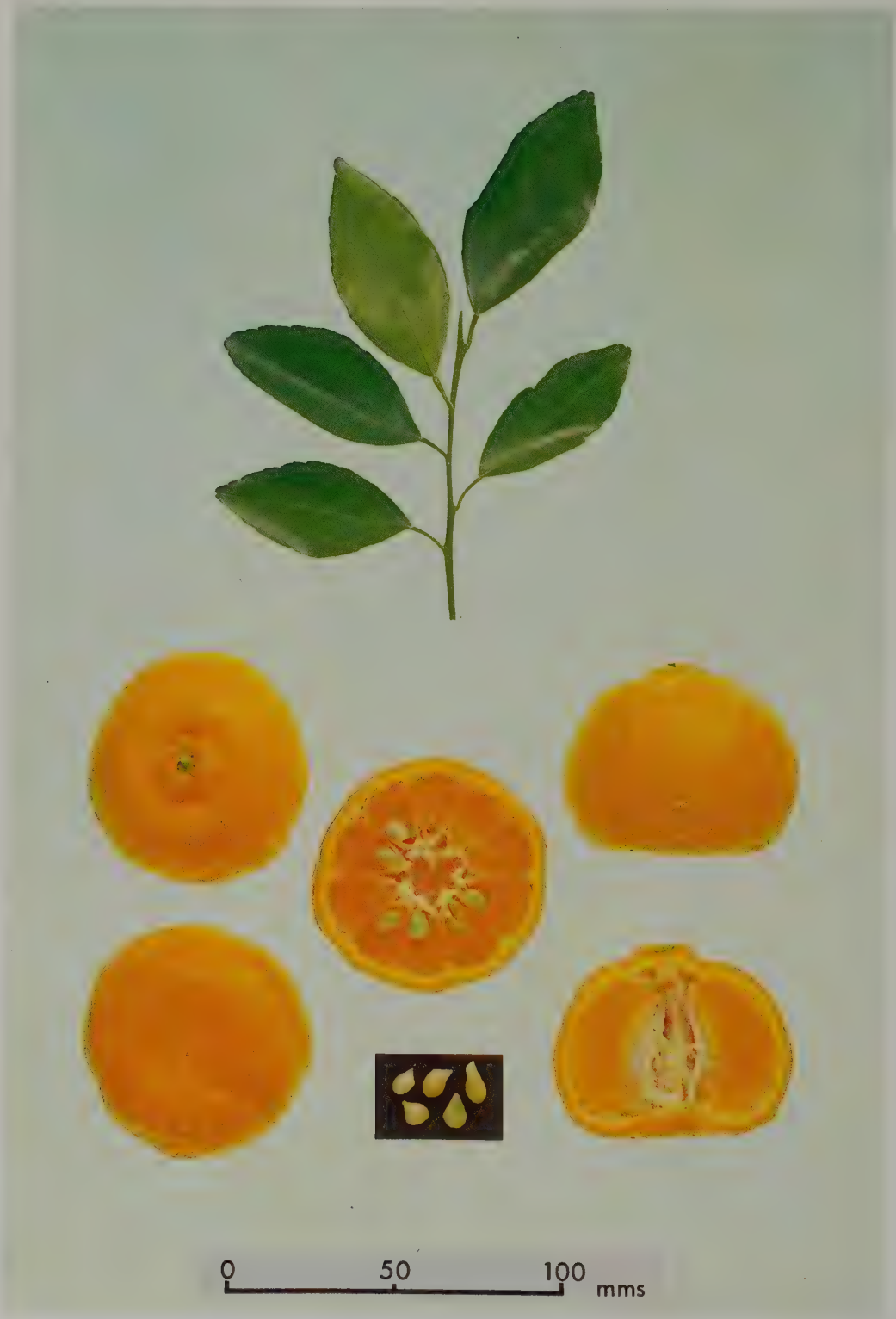
Mandarin trees are smaller, more upright, less vigorous, practically thorn-free and have smaller leaves than orange trees. The petioles are articulated and have smaller wings than oranges. Leaves vary in shape between varieties from long and narrow, uniformly tapered to both ends and in some instances with wavy margins, to broader and stiffer leaves closely resembling those of oranges. Fruits are generally smaller than oranges and their maturity season extends from earlier than navels to early in the Valencia season. They have thinner and finer skins and a softer flesh with less pith and fibre than oranges. They are generally seedy but seedless fruits are produced when pollination varieties are lacking. The satsuma group which is extensively grown in Japan is seedless. Apart from these, seedless fruits are generally smaller than seedy fruits although fruit size is markedly affected by crop size. Seeds are plump with white seedcoats and green cotyledons.

In parts of Queensland crop size is adjusted by pruning away approximately one third of the shoots each year and in other states by chemical thinning sprays. Without crop size control there is a marked tendency for trees to overcrop and become biennial bearing.

The main varieties grown are the Imperial (early season), Emperor and Dancy (mid-season), Ellendale and Kara (late season). Ellendale is a tangor – a hybrid of mandarin and orange. Other varieties grown to a limited extent include Silverhill, Unshiu (satsuma types), Scarlet, Wallent and Hanson. The latter two are Ellendale seedling varieties while Silverhill and Unshiu are more suited to cooler environments.

Imperial This variety originated at Emu Plains near Sydney about 1890 and is thought to be a chance hybrid of Willowleaf and possibly Emperor (Bowman 1955).

It is early maturing and has a pale orange skin, a depressed base and a slight neck. It matures earlier than the navel orange and has an excellent, tangy, mandarin flavour. In Australia large fruits bring premium prices early in the

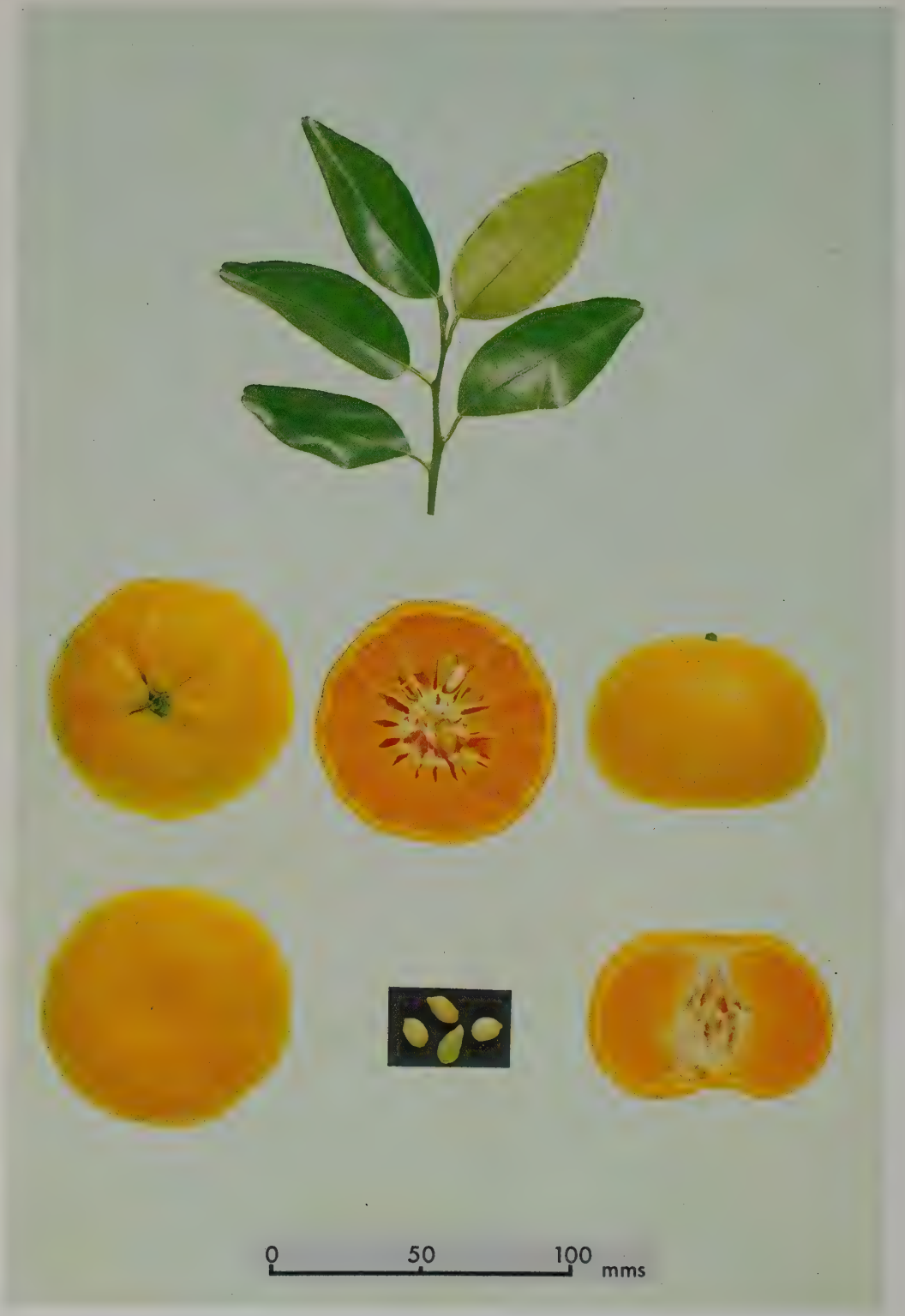


EMPEROR MANDARIN

HRS Dareton July 1978

DANCY MANDARIN

DHR Merbein June 1982



ELLENDALE MANDARIN

DHR Merbein November 1978

season but are less sought after late in their season because of a tendency to "puffiness" caused by the skin separating from the flesh.

Emperor The Emperor is a very old variety which closely resembles and is possibly a seedling of the Nagpur Santara, the major commercial citrus variety of India or the Ponkan which is widely grown in southern China and Taiwan. It was introduced to Australia soon after European settlement.

It is a mid-season variety with a brighter orange skin and a larger fruit than the Imperial. The fruit is flattened and often has a rough irregular shape. It has a depressed blossom end and a smaller neck than the Imperial. Like the Imperial it generally has only a few seeds. Its flavour is excellent but not as tangy as the Imperial or Ellendale.

Dancy Like the Emperor, the Dancy is a very old variety which probably originated in India. It has medium sized fruit, slightly depressed at the base and slightly necked at the stem end. It has a thin, loose skin which at maturity is bright orange.

If stored on the tree when mature, fruit tends to deteriorate – the skin tends to become puffy and the flesh loses juice and becomes dry and woody.

Dancy has a strong tendency to biennial bearing.

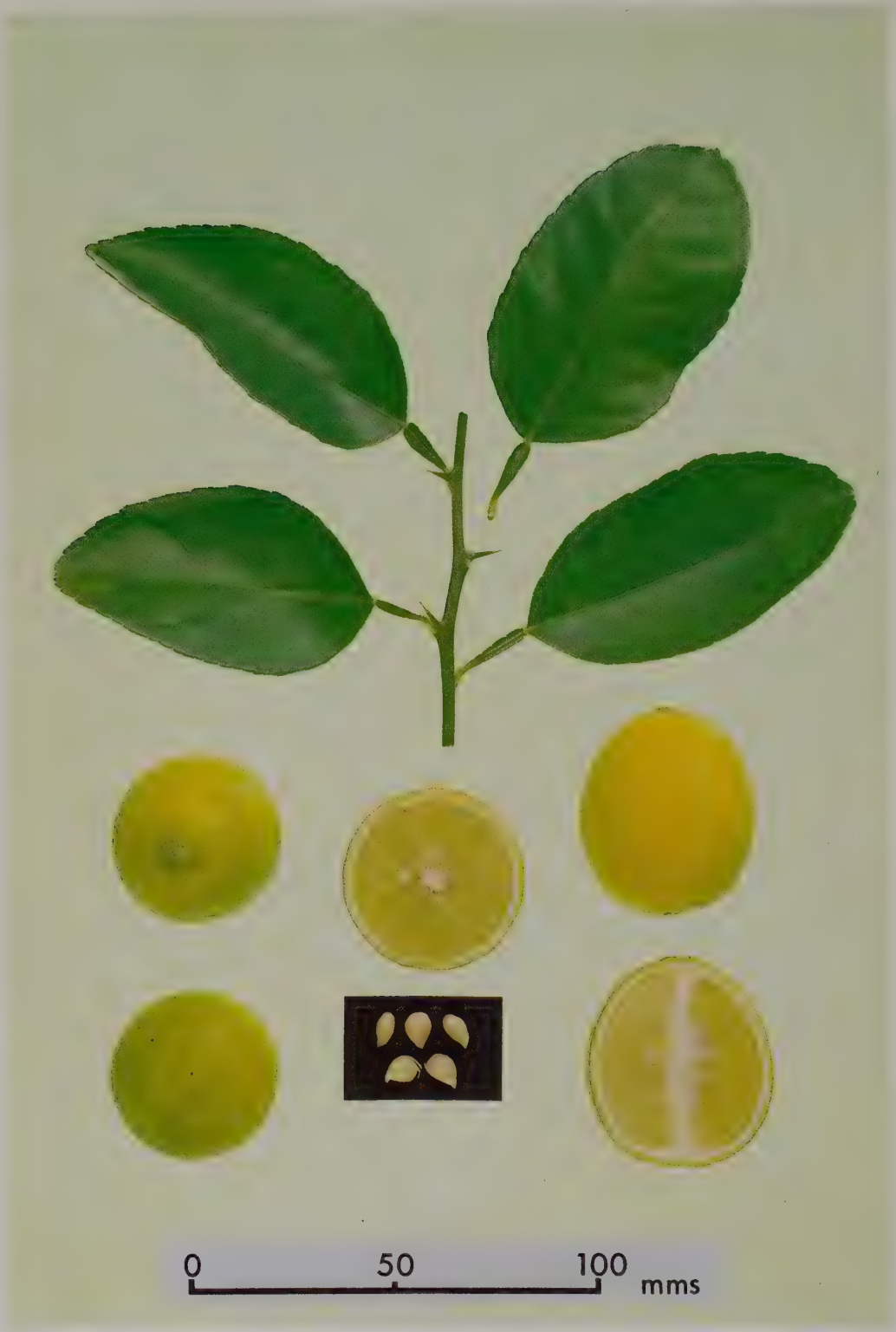
Ellendale This is a late maturing variety which has characteristics of both its mandarin and orange parents. It originated in the Barrum district of Queensland about 1878 from an introduction of seed from China.

The fruit is large and flattened with a smooth, bright orange, thin but relatively tight skin. A small navel is evident on about half the fruits. The fruit has excellent keeping qualities.

The tree more closely resembles that of the orange than the typically upright and bushy mandarin.

Ellendale grows to perfection in inland districts of Queensland but often develops cracked and split skins in more humid, coastal districts.

Kara This variety is an artificial hybrid of Owari satsuma and King mandarin made in 1915 by H.R. Frost at Riverside, California. It is very late maturing and is gaining in popularity because of its bright orange skin colour and the high quality of its flesh which has an excellent tangy flavour.



WEST INDIAN LIME

DHR Merbein June 1978

Lime

Citrus aurantifolia (Christm.) Swing.

Limes are thought to have originated in the southern Himalayan region extending from north eastern India and Burma to northern Malaysia. Their origin and spread to Europe and subsequently Australia is obscure.

Although the juice is used in most tropical countries for a refreshing drink, limes have been grown to only a very limited extent in Australia. The ravages of tristeza which is spread by the black citrus aphid *(Toxoptera citricidus)* have maintained this situation. However the availability of new West Indian lime clones with mild strain protection against tristeza may lead to the establishment of a small viable lime industry in the north of Australia. In tropical regions of the Northern Territory and Western Australia where the black citrus aphid is not found, experimental plantings of limes are already producing excellent crops.

The lime is an acid fruit and has a characteristic flavour. It is more cold sensitive than the lemon and the tree is less vigorous with smaller leaves. There are two major commercial cultivars overseas. The West Indian, Mexican or Key lime is grown commercially for juice, skin and seed oil mainly in Mexico, the West Indies, India and Egypt. The Persian or Tahiti lime is the main commercial variety of Florida.

West Indian lime This variety has small fruit with thin skin which is lime green at maturity in the tropics but becomes pale lemon in colder situations. It reaches its peak of flavour and aroma if harvested at the colour change from dark to light green (silver-green). The flesh is pale green and seedy. Juice contains more acid but less vitamin C than the lemon.

In tropical Australia it is everbearing but crops heaviest in November and late February. The fruit drops from the tree when fully mature. Both thorny and thorn-free clones are known. Leaves are small and unlike the lemon have winged petioles.

Tahiti or Persian lime This variety was introduced into Australia in 1824 (Bowman 1955) but has never gained commercial prominence. It is thought to be of hybrid origin, one parent being the acid lime and the other either lemon or citron. It has seedless fruit which more closely resemble small lemons than the West Indian lime. It is more cold tolerant than the West Indian lime but lacks some of its flavour and aroma.

The tree is more vigorous than that of the West Indian lime and carries larger leaves with winged petioles.

PUMMELO

DHR Merbein August 1982

Pummelo

Citrus maxima (Burm.) Merrill
(Citrus grandis(L.)Osbeck)

This species almost certainly originated in the Malaysia-East Indies region and was distributed from there to India and China in early times. From there it spread to the Mediterranean regions and throughout Europe.

Most varieties have inferior fruits with very thick skins, abundant seed and low juice contents but there are some which are highly prized in southern China and south east Asia where they are grown commercially.

In Australia pummelos are not grown commercially but have some potential where grapefruit cannot be grown successfully. They lack the bitter flavour of grapefruit and, particularly in the tropics, can provide a refreshing drink or breakfast food. Owing to their thick skins pummelos are rarely damaged by insects and fruits can be stored for considerable periods without deterioration.

The pummelo differs from the grapefruit in several respects. The fruits are larger with thicker skins, the young shoots, flowers and fruits are pubescent, the seeds are mono- rather than polyembryonic and the carpellary membranes are much thicker and tougher. The membranes can readily be split open to free the large juice vesicles which remain intact.

The pummelo is less cold tolerant than grapefruit but has a comparable heat requirement to mature its fruit.

It resembles grapefruit in the general shape and vigour of the tree and in having broad leaves with broadly winged petioles. However a wide range of tree forms ranging from low and spreading to tall and upright are known. White and pink fleshed varieties are known for both species. As with grapefruit, best colour development in the pink fleshed varieties occurs in the hot, arid but frost-free regions of northern and Western Australia.

When grown in the tropics the skin colour is normally pale green or pale lemon.The deeper tinted skin of the photographic specimen developed after exposure to low winter temperatures.

PALESTINE CITRON

DHR Merbein December 1982

Citron

Citrus medica L.

The citron is of special interest because it is one of the earliest cultivated fruits. Its origin is not documented but its cultivation dates to the Persian, Greek and Roman empires.

The citron was imported into Australia soon after European settlement (Bowman 1956) but it is not now grown commercially. It is included in collections as a source of material for indexing for exocortis and for breeding material. In early times in Australia the sweet aromatic peel was used for flavouring in cakes and confectionary but lemon peel is now used for this purpose.

Citron peel has been used as candy after fermentation in sea water and soaking in sugar solutions of increasing concentrations before drying. Dried peel is also reputed to have good moth-repellant properties.

The citron grows to a small straggly tree up to 5m high. It is more sensitive to frost than the lemon but not as frost sensitive as the West Indian lime. Leaves are oval-shaped with a serrated edge and have short wingless petioles which are not articulated. Most shoots carry a short stiff spine at each leaf axil.

Fruits have very thick, fragrant, uneven, lemon or pale orange skins. There are several cultivars overseas which differ in fruit shape, skin colour, and acidity and bitterness of flesh.

Those in Australian collections include the Palestine and Etrog which are lemon shaped but larger than lemons. The Etrog has a persistent style which remains and enlarges as the fruits mature. Both varieties have pale lime-green acid flesh which is very seedy.

In China and Japan dwarf forms of the fingered citron or Buddha's hand (*C.medica* var. *sarcodactylis* Noch.) are highly prized for their perfume and ornamental value. In these forms carpels do not fuse and fruits somewhat resemble a hanging hand.

MINNEOLA TANGELO

HRS Dareton June 1982

Tangelo

C.paradisi x *C.reticulata*

The characteristics of this hybrid vary from those which most closely resemble mandarins to those which closely resemble grapefruits. They can be grown wherever grapefruits are grown successfully. They have thinner skins which peel more readily than grapefruit. Their flesh is finer textured with thinner carpellary walls and less of the bitter flavour component of grapefruit. Like grapefruit, fruits develop their best flavour under hot arid conditions. Petioles are articulated and have small wings resembling mandarins.

Loose-skinned mandarin-like varieties include Minneola, Orlando, Seminole and San Jacinto while the Wekiwa, which is a grapefruit-tangelo hybrid, more closely resembles grapefruit.

Tangelos are not grown commercially in Australia to any great extent but interest in them is increasing in northern and Western Australia.

Minneola This is an artificial hybrid of Duncan grapefruit and Dancy mandarin produced in Florida between 1908 and 1912 (Reuther *et al.* 1967). It was released there in 1931. It is a mid to late season variety. Fruits have bright orange, thin, smooth and moderately adherent skin. They are comparable in size to oranges but are oblate to obovate in shape and have a distinct neck. The pulp has an excellent tangy flavour. It is bright orange, tender and juicy with thin carpellary membranes, little pith and only moderately seedy. Seed cotyledons have a greenish tinge resembling their mandarin parent. Cross-pollination is necessary for consistent and heavy cropping. Mandarin varieties such as Dancy are effective pollinators.

Orlando This variety has the same parentage and history as Minneola. Fruit matures earlier than Minneola and is sweeter but lacks the neck of the Minneola. Its fruits are oblate with a smooth bright orange skin flattened at both the stem and blossom ends. The flesh resembles Minneola in colour, texture and seediness. The tree has distinctly cupped leaves which are smaller and more oval than those of Minneola. It is considered more cold tolerant than Minneola and like Minneola requires cross-pollination for satisfactory cropping.

Seminole This variety also has the same parentage and history as Minneola. It is late maturing and unlike Minneola and Orlando is self fruitful. The fruit is oblate and has slightly pebbled deep orange rind. The flesh is bright orange and seedy and has a rich flavour which is more acid than Minneola and Orlando. Like Orlando the tree has cupped leaves.

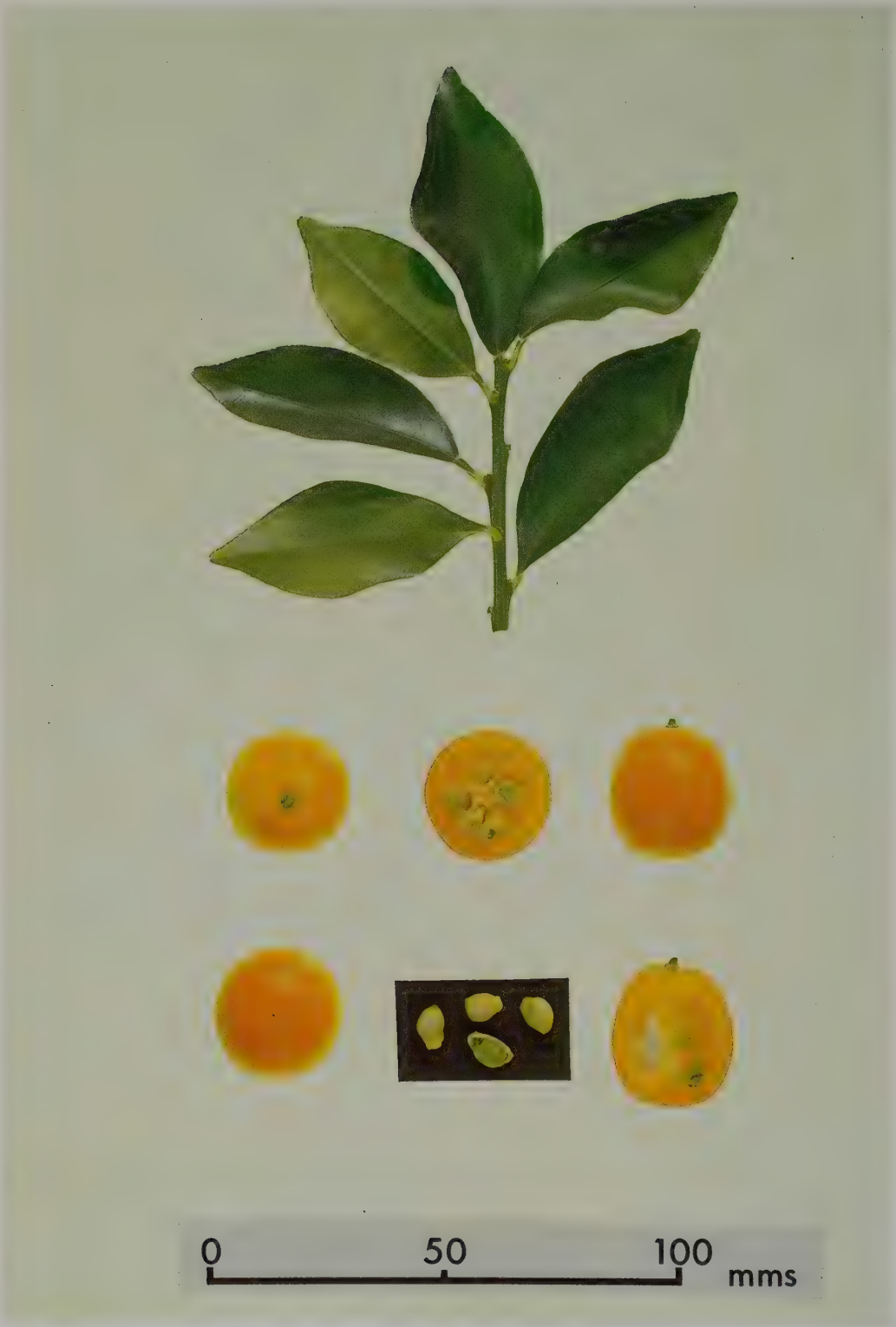
San Jacinto This is a hybrid of unknown parentage. It originated at Indio, California and was released there in 1931. Its fruit is round to obovate with orange-yellow skin and like Orlando is early maturing. It peels more readily than Minneola, Orlando or Seminole. The flesh is light orange, tender and

ORLANDO TANGELO
HRS Dareton May 1982

SEMINOLE TANGELO
HRS Dareton May 1981

juicy and has a pleasant tangy flavour. Like the other tangelos the tree is vigorous and productive. Its leaves are medium sized, oval shaped and pointed and do not cup.

Wekiwa This variety has many features resembling grapefruit. Its fruit is spherical to pyriform, generally smaller than grapefruit and has a thick, pale yellow, moderately adherent skin which often has a pink blush. When grown in favourable, hot arid regions the flesh colour becomes bright pink. The flesh is tender and juicy with less bitterness than grapefruit and is moderately seedy. The tree is less vigorous than the above mentioned tangelos but is very productive. Its leaves are oval and not cupped.



MEIWA KUMQUAT

DHR Merbein Glasshouse June 1982

Kumquat

Fortunella spp.

Kumquats have been grown in China and Japan for centuries and were classified under *Citrus* until Swingle (1915a) established the genus *Fortunella.*

They are extremely cold tolerant and have small, orange skinned, edible fruits with up to seven (generally three to five) locules (segments). Skins are sweet flavoured, spicy and also edible.

Kumquats are used extensively for ornamentals because of their bright glossy leaves and bright orange fruits. They can readily be propagated from cuttings but also can be budded to *P.trifoliata,* Cleopatra mandarin and calamondin rootstocks. Fruits make an excellent marmalade and are also used for flavouring liqueurs.

Meiwa Although Swingle classified this variety as a true species *(F.crassifolia)* he later concluded that it was a hybrid of the oval kumquat *(F.margarita* (Lour.) Swing.) and the round kumquat *(F.japonica* (Thunb.) Swing.)

The Meiwa has a larger fruit (up to 5cm diameter) with sweeter flesh and a sweeter skin than other kumquats. It is slightly elongated and commonly has seven locules and few seeds. The seeds are plump and have white testas, and like mandarins have green cotyledons. The leaves are small, narrow and pointed and the tree is less vigorous than other citrus.

Nagami or oval kumquat *(Fortunella margarita* (Lour.) Swing.) This is the most commonly grown kumquat in China, Japan and the United States. It has oval fruit with a sweet skin but has more skin oil than the Meiwa. Fruits have deep orange skins, four or five locules and few seeds. The tree is vigous and prolific with larger leaves than other kumquats.

Marumi or round kumquat *(Fortunella japonica* (Thunb.) Swing.) This kumquat resembles the Nagami but has rounder fruit with four to seven locules.The skin is sweeter than the Nagami but not as sweet as the Meiwa. The tree is less vigorous than the Nagami and leaves are smaller and blunted at the point.

Hong Kong kumquat *(Fortunella hindsii* (Champ.) Swing.) This variety grows wild in Hong Kong and adjacent regions of China. It has very small oval leaves and small bright orange fruits about 1cm in diameter. Both tetraploid and diploid forms are cultivated. The diploid form has thinner and larger leaves but fruits are similar.

Other ornamental citrus

The calamondin, which Tanaka classified as *Citrus madurensis* Lour. is now thought to be a hybrid with *Fortunella* and sour mandarin parentage.

NAGAMI KUMQUAT

HRS Dareton December 1982

CALAMONDIN

HRS Dareton June 1982

The calamondin resembles the kumquats in having small (3 to 7 cm diameter) orange skinned fruits each with several seeds having green cotyledons. It is widely used as an ornamental but lacks the sweet fruit and sweet skin of the kumquats. The tree has moderate vigour and is highly productive. The fruits can be used for jam and liqueurs.

Variegated forms are known and are also used for ornamentals.

AUSTRALIAN DESERT LIME

DHR Merbein December 1982

Australian desert lime *Eremocitrus glauca* (Lindl.) Swing.

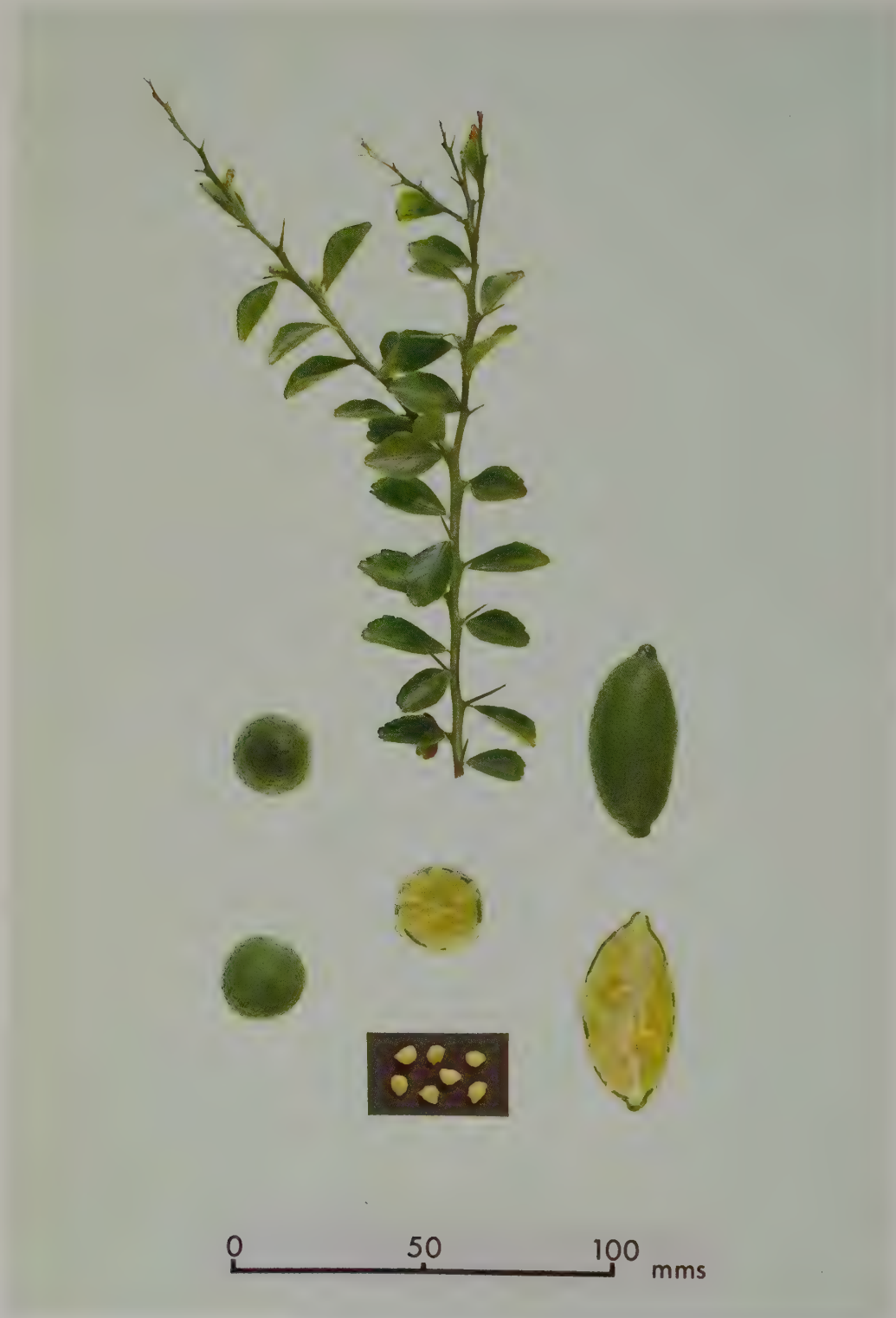
This species occurs over a large arid area of eastern Australia. It is very drought tolerant and can withstand both very hot (45°C) and very cold (−24°C) conditions. Of all species of Aurantioideae it has the shortest time from flowering to fruit maturity; about eight weeks.

The habitat of this species extends from Rockhampton to Longreach in Queensland, south to Dubbo in central New South Wales and west to Quorn in the Flinders ranges of South Australia. In the western part of this area it occurs in isolated clumps of up to several hundred trees which are as much as 100 km apart.

The tree varies in size from a small, thorny, multi-stemmed, shrubby thicket only 2 or 3m high, to trees up to 8m high with rounded crowns and a 2m trunk to tall, narrow, upright trees up to 12m high with a well defined trunk. When a tree is seriously damaged it tends to sucker prolifically from the roots to form an impenetrable, thorny thicket. The leaves are grey-green, long and narrow with practically no petioles and no articulation. They have thick cuticles and differ from true *Citrus* fruits in having both upper and lower surfaces similar. Both surfaces have a palisade layer, sunken stomates and hairs parallel with the surface on young leaves. Trees vary in thorniness. The single spines are short, stout and only a few cm long on some trees while on others they are long and narrow and up to 8cm long (Swingle 1914, Armstrong 1975).

Flowers are small, white with four or five petals and some are complete while others lack a fully developed stigma and are male-functional only. The stamens are free and number four times the petals. The fruit resembles a small lime. It is round to oblate (occasionally pyriform) about 2cm in diameter, with a light yellow-green almost translucent skin with obvious small oil cells. Fruits are often seedless but some have a few small plump seeds with a wrinkled seed coat. Seeds are often parasitised by a gall wasp (a species of *Eurytama)* which causes large galls to develop in place of the seeds.

The species has been hybridised with a range of true *Citrus* species including sweet and sour orange, mandarin and kumquat. It has been successfully grafted to the true *Citrus* species and to *Microcitrus.*



AUSTRALIAN FINGER LIME

DHR Merbein March 1981

Microcitrus

The genus *Microcitrus* was separated from *Citrus* by Swingle (1915b) based on the minute size of the flowers and juvenile leaves, the slender twigs and the small fruits containing four to eight locules. He took account also of the dimorphic foliage, the parallel vein enation, the short wingless petioles and the short pistils and numerous free stamens.

Seven species have been described and of these, five, namely *M.australasica, M.australis, M.garrowayi, M.inodora* and *M.maideniana* are Australian natives. The other two, *M.Warburgiana* and *M.papuana* are native to New Guinea.

The Australian species occur in rainforest extending from northern New South Wales to the Cape York peninsula on the coastal side of the Great Dividing Range. One species, probably *M.australasica* also occurs in the Northern Territory in the vicinity of Darwin.

Finger lime *(Microcitrus australasica* (F. Muell.) Swing.) This species occurs in rainforest where it grows into a tall narrow tree up to 10m high. It has dimorphic foliage. Young seedlings develop only horizontal branches which have thorns about twice as long as the small, juvenile leaves. After the initial horizontal branches with very short internodes have developed, one or more upright shoots grow very rapidly and the size of the new leaves increases from the narrow cataphylls at the base to the mature form (1.5–4cm by 1.2–2.5cm) with a blunt apex.

The flowers occur singly in the axils of the leaves. They are round or pyriform with three to five petals and 12 to 20 free stamens. The fruits are long and narrow (6.5–10cm x 1.5–2.5cm) with thin, green, yellow, purple or black skins, blunt points at both ends and five to seven locules. The juice vesicles are compressed so that when the skin is cut they tend to burst out. They contain an acid juice with very little sugar. Seeds are plump and are like those of a lemon but much smaller. In the mature form slender single spines arise alongside the petiole at each node.

Australian round lime or dooja *(Microcitrus australis* (Planch.) Swing.) This species thrives in drier conditions than *M.australasica.* It occurs as a tall slender upright tree (9 to 18m high) on the edges of rainforest in the vicinity of Brisbane and further north. It has dimorphic foliage with narrow, linear, juvenile leaves and mature leaves, 2.5–5cm long, which are widest towards the middle. Fruits are round and rough skinned, 2.5–8cm diameter, and have five or six locules. The skin is green turning lemon coloured at maturity. The flesh is similar to *M.australasica.*

Russell River lime *(Microcitrus inodora* (F.M. Bail.) Swing.) This species is known only from lowland rainforest in the high rainfall area between Cairns and Innisfail. It is so named because of the absence of perfume from the flowers. It is a shrub or small tree, 2–4m high, with large leaves,

AUSTRALIAN ROUND LIME

DPI Brisbane April 1982

short wing-less petioles which are not articulated with the blade and fruits which are ribbed. The fruits are oval or oblong shaped, up to 6.5 x 3.2cm with eight locules, and, like other *Microcitrus* species, have a pulp with a pleasant tasting but very acid juice. This species differs from other *Microcitrus* except *M.maideniana* in having two spines in each leaf axil.

Mount White lime *(Microcitrus garrowayi* (F.M. Bail.) Swing.) This species resembles *M.australasica* but it occurs in the far north of Queensland. It has broader leaves and shorter, thicker fruits with fewer locules (four to five) than *M.australasica.* The external appearance of the skin is rougher than the finger lime owing to large convex oil cells.

The specimen photographed had been preserved in formalin: acetic acid: alcohol (F.A.A.) and does not show the normal pale lemon skin and light green flesh of the fresh fruit.

Maiden's Australian wild lime (Microcitrus maideniana (Domin.) Swing.) This species resembles *M.inodora* in origin, ribbed fruits and twin spines. It differs in having a distinctly sunken apex.

MOUNT WHITE LIME CSIRO DFR Atherton (Pickled specimen)

TRIFOLIATA

DHR Merbein May 1981

Rootstocks

Seedling citrus cultivars have encountered problems and become unthrifty in many countries of the world due to root fungi, drought, nematodes or salinity. To overcome these problems citrus is now almost universally propagated by budding onto rootstocks. This practice has led to a new set of problems due to virus and virus-like diseases which are common in old line trees and are transmitted by vegetative propagation, but are not transmitted through seed. For a healthy citrus industry a considerable and continuing effort is necessary to provide virus tested budwood to nurserymen and growers. Trees propagated vegetatively do have the advantages of higher production, greater uniformity of product, and of being less thorny and more manageable than seedlings.

Rootstocks available in Australia vary considerably in their resistance to root fungi, virus diseases, nematodes and salinity. They also differ in longevity, mature tree size, drought and cold tolerance and in their influence on production and fruit quality. Because the virus disease tristeza is widespread and is transmitted by the black citrus aphid, rootstock scion combinations need to be tolerant of this disease except in the Northern Territory where the aphid vector is unknown.

On sites where citrus has been previously grown there is a build-up of fungi and nematodes in the soil which may affect the development of young citrus planted in the same area. To avoid this retarded development only rootstocks tolerant or immune to soil fungi and nematodes should be grown in such replant situations.

The major rootstocks used in Australia include trifoliata, sweet orange, citrange, citronelle and Cleopatra and Emperor mandarin.

They are all highly polyembryonic but do occasionally produce hybrid progeny. The performance of such hybrids as rootstocks is uncertain and whenever they are recognised hybrid seedlings are discarded in the nursery.

Apart from the sweet oranges,which are seedy mid-season cultivars, and Emperor mandarin, fruits of rootstock varieties are unpalatable. Citronelle is inferior to lemon but may be used as a lemon substitute. Fruits of trifoliata and its hybrids are very bitter while fruits of Cleopatra mandarin are very acid and very seedy.

Trifoliata *(Poncirus trifoliata* (L.) Raf.) This stock is most suitable for lime-free soils and can withstand cold and wet conditions. It has excellent root fungus and nematode tolerance but is susceptible to high chloride levels in soils or irrigation water. Fruit quality for trees on this rootstock is excellent with high juice and total soluble solids contents. It has a good capacity for supplying nitrogen, phosphorous and potassium to the tree but, particularly on alkaline soils, trees can become

PARRAMATTA SWEET ORANGE

DHR Merbein June 1981

CARRIZO CITRANGE

DHR Merbein June 1981

CITRONELLE
DHR Merbein June 1981

CLEOPATRA MANDARIN
DHR Merbein September 1981

deficient in zinc, manganese, copper and iron. For storing Valencias on the tree this stock has been less successful than others because of the early onset of regreening and loss of juice. If scionwood is infected with any but very mild strains of the viroid disease exocortis trees may be stunted and unthrifty. Lemons, other than virus tested Lisbons, have similar problems and are not recommended on this stock.

Sweet orange is widely used on virgin, well drained soils. It is more tolerant of chloride than trifoliata but is less tolerant of soil fungi, nematodes and water-logging. In replant situations this rootstock has been unsatisfactory and is not recommended.

Citrange *(C.sinensis* x *P.trifoliata)* is a widely used rootstock, the performance of which is intermediate between that of its parents. It has sufficient tolerance of soil fungi and nematodes to be suitable in replant situations. Like trifoliata it is intolerant of exocortis and cannot be used for lemons other than exocortis-free Lisbons. There are several varieties of citrange in use. Troyer and Carrizo citranges both of which originated from the same cross of Washington navel with *P.trifoliata* made in California in 1909 (Savage and Gardner 1965) have very similar field performance. The Rusk citrange which developed from a cross of Ruby blood orange and *P.trifoliata* made by Swingle in 1897 is considered a good rootstock for navel oranges but has relatively low seed numbers. The Benton citrange originated in Australia and is showing promise in recent trials with oranges and in replant situations with Eureka lemons.

Citronelle *(C. jambhiri* Lush.) This rootstock was widely used in early Australian development because of its ease of propagation, excellent nursery characteristics and drought tolerance. Trees on this rootstock are vigorous with high early yields but are generally short-lived and become unthrifty after about 15 years except on very well drained, sandy soils in arid areas where water management is very good. Scion fruit quality is generally poor with low juice and total soluble solids content. It is not recommended for mandarins or Ellendale tangor.

Cleopatra mandarin has good tolerance of soil fungi, nematodes, salinity and lime and is used for heavier textured soils than those considered ideal for citrus culture. On this rootstock trees are slow growing with low yields in early years but are long-lived and outyield most other stocks after about 20 years. Scion fruits tend to be small but have excellent quality.

Emperor mandarin has similar performance to Cleopatra but is less tolerant of salinity and lime and tends to produce lower yields of smaller fruit. Like Cleopatra it is slow growing in early years but is long-lived.

Rangpur lime *(Citrus reticulata* var. *austera* hyb. or *Citrus limonia* Osbeck) This has good tolerance of drought, salinity and lime but is only moderately tolerant of soil fungi. It is susceptible to exocortis and only

RANGPUR LIME

DHR Merbein May 1981

virus-free budwood can be used. It is similar to citronelle in imparting to the scion vigorous early growth and producing high yields of low quality fruit. It performs best with lemons and limes.

Sour orange Because of its susceptibility to tristeza this stock cannot be used with sweet-fruited scions but is satisfactory with lemons and limes. It has excellent soil fungi, nematode, cold and drought tolerance and imparts high quality to fruit.

Macrophylla *(Citrus macrophylla* Wester) This rootstock has shown promise for lemons but only if they are budded before the seedlings become infected with tristeza. It cannot be recommended for sweet-fruited scions.

Sacaton citrumelo *(C.paradisi* x *P.trifoliata)* This rootstock has shown promise for lemons, grapefruit and tangelos in India and Florida but has the disadvantage of seedling variability.

Table 4. Desirable scion rootstock combinations.

Rootstocks	Scion varieties							
	Sweet orange	Lemon	Grape-fruit	Mand-arin	Tangelo	Lime	Pum-melo	Kum-quat
Sweet orange	S2,3	S3	S3	S2,3	S	S	S	U
Trifoliata*	S1,2	Lisbon only 1,2	S1,2	S1,2	S	S	S	S
Citrange*	S1,3	Lisbon only	S	S	S	S	S	U
Citronelle	S3	S1,2, 3,4	S4	U+	S	S	S	U
Sour orange	NR	S4	NR	NR	NR	S	NR	NR
Cleopatra mandarin	S1	U	S3	S3,4	S	U	U	S
Emperor mandarin	S	U	S	S4	S	U	U	U
Rangpur lime*	S	S	S	U	U	S	S	U

*Require scion free of exocortis to prevent stunting
+Ellendale gives an unsatisfactory union, Imperial gives a short-lived tree

S=Graft compatible, tree capable of good growth, high yield and long-lived
U=Combination undesirable
NR=Not recommended

Recommended for
1. Subtropical coastal regions subject to high rainfall
2. Inland regions with good quality water for irrigation
3. Inland regions subject to high salinity
4. Tropical regions

Further Reading

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